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XV. On the Errors in Longitude as determined by Chronometers at Sea, arising from the action of the iron in the ships upon the Chronometers. By GEORGE FISHER, Esq. Communicated by JOHN BARROW, Esq. F. R. S.

Read June 8, 1820.

THE determination of the longitude at sea by timekeepers, is so exceedingly easy from the simplicity of the observations and calculations employed, and from the general practicability of the method, as to render chronometers, in the present improved state of navigation, almost indispensable articles in the equipment of ships for foreign service ; and I shall feel happy if the following observations may, in any way, contribute to the more accurate determination of the longitude by this method.

The sudden alteration in the rates of chronometers when taken on board of ships, has been frequently observed by intelligent seamen ; and is generally ascribed to the motion of the vessels. Before, however, I attempt to account for this alteration, I shall first prove that it actually takes place ; and, in order to do this, shall relate the circumstances connected with the chronometers on board the *Dorothea* and *Trent*, commanded by Captain BUCHAN, which occurred during the late voyage to the North Pole.

Soon after the arrival of the ships on the coast of Spitzbergen, the chronometers on board the *Dorothea* (five in number) were found to be rapidly gaining on their former

rates as determined in London previous to the ship's sailing ; in consequence of which the land appeared considerably to the westward of its true position as determined by lunar observation, and they were found to be still gaining daily, which appeared not only from each subsequent set of lunars, but also by comparing the longitude of different points of land determined by the chronometers, with the longitude of the same points ascertained in the same way some time afterwards.

For instance ; the longitude of a remarkable point of land on the north-west coast of Spitzbergen, called Cloven Cliff, was found by a mean of the observations taken with the chronometers on June 21, 1818, to be $10^{\circ} 35' 27''$ E ; but the longitude of the same point of land on July 31, was $10^{\circ} 15' 37''$ E, making a difference of no less than about 20' of longitude in five weeks ; that is, estimating the longitude with the same rates and errors as determined in London before their departure ; from this, therefore, it appears, they had been gaining on their former rates, or had been increasing their gaining rates, and diminishing their losing ones.

An opportunity soon afterwards occurred of observing the effect produced upon the chronometers by removing them on shore. On the 9th of August, the chronometers, nine in number, were landed on an island, where a temporary observatory had been erected for the purpose, and the latitude of which had been accurately determined with a repeating circle made by TROUGHTON, when it was found that the acceleration immediately ceased ; for the longitude of the place by chronometers, August 12, was $9^{\circ} 42' 36''$ E, but on the 27th, it was $10^{\circ} 1' 0''$ E, making a difference of $18' 24''$ of longitude in fifteen days, using the former rates.

Since, therefore, the chronometers were *getting easterly*

by their removal on shore, the acceleration must have ceased ; which will appear upon consideration.

A similar circumstance was observed by Lieut. FRANKLIN to take place with the chronometers on board the Trent, which were four in number ; and he observes, " It may be " worthy of remark, that the chronometers taken out by the " Hon. Captain PHIPPS, showed too great westerly longitude, " and consequently gained on these seas. The fact of so " many chronometers altering their rates the same way, is " curious, but I am not aware that any cause can be as- " signed."

The effect produced upon one or two of the chronometers by their removal to land, was very remarkable ; a chronometer made by BAIRD was (by observations taken on shore near where the ships lay at anchor, by Lieutenants FRANKLIN and BEECHEY, with false horizon, and eight inch reflecting circles of TROUGHTON, from August 8, A.M. to 12, P.M.) losing 3,"4 daily when on board ; but upon its removal on shore to the observatory, its rate per transit, from August 16, to 26, was observed by myself to be 18,"2 losing. Upon again removing it on board, it was found by observation, as before, to be losing 6,"5 daily ; from which it appears the chronometer lost no less than about thirteen or fourteen seconds daily by its removal on shore.

Another chronometer in the Trent, made by PENNINGTON, had been gaining rapidly on board ; when taken on shore, it acquired immediately a losing rate of 1,"8, nearly the same as it had in London before the vessels sailed.

A chronometer of my own, by ARNOLD, was affected likewise nearly as much, losing about 9" daily by its removal on shore.

In the other chronometers the alteration was less sudden, but was ultimately not less considerable; and they were several days on shore before they acquired a steady rate, as will appear by the following table of their rates, during the interval of the respective dates.

Table of Rates of Chronometers immediately when landed, August 9th, 1818.

	No. 1. Earnshaw.	2. Arnold.	4. Barraud.	5. Arnold.	Clock.
August 9	+12,0	—0,2	+8,1	—33,5	
11	+10,2	0,	+7,9	—34,2	
12	+7,98	—1,85	+0,8	—36,2	+70,60
16	+6,2	—5,1	+7,1	—40,9	+69,03
20	+5,63	—5,2	+2,8	—37,7	+69,12
23	+4,02	—6,14	+4,3	—41,5	+69,29
26					

The rates from August 12 to 26, were determined by the sun's transit, and those from August 9th (the day on which the chronometers were landed) to the 12th, by a comparison with the clock, supposing its mean rate +69,"5, as no observation occurred during this interval; and by this table it appears, that the chronometers when landed were rapidly diminishing their gaining rates, and increasing their losing ones. In the others the effect was almost immediate.

The clock and chronometers were likewise landed upon a small island in Fair Haven, on the north coast of Spitzbergen, on the 30th June; and, as the same circumstances occurred, it will be needless to detail them.

The following table is intended to show the difference

between the rates on board the ships and what they would have been had they been on shore.

Chronometers.	Error, Greenwich time.	Difference.	Interval.	Mean Rates at Sea.	Mean Rates on Shore.
No. 1. Earnshaw.	April 11, + 7.40.1 Aug. 25, + 26.32.2	+ 18.52.1	days. 136	+ 8.0	+ 3.8
2. Arnold.	April 11, — 0.42 Aug. 25, — 4.15	— 3.33	136	— 1.5	— 5.2
3. Arnold.	May 7, — 1.44 July 2, — 3.36	1.52	56	— 2.0	— 6.5
4. Barraud.	April 1, — 0.1 Aug. 25, + 5.55.5	+ 5.56.5	146	+ 2.5	+ 1.2
5. Arnold.	April 15, — 0.38 Aug. 25, — 28.48	— 28.10	132	— 12.8	— 22.4
6. Earnshaw.	April 11, + 1.13 Aug. 25, + 0. 2.2	— 1.10.8	136	— 0.5	— 0.93
7. Pennington.	April 11, + 0. 53 Aug. 25, + 13.57	+ 13.3.5	136	+ 5.8	— 0.63
8. Arnold.	April 13, — 0.24 Aug. 25, — 15.53.5	+ 16.17.5	134	+ 7.3	— 2.5
9. Baird.	April 15, + 0.25.1 Aug. 25, + 5.12.5	+ 4.47.4	132	+ 2.2	— 5.15

The errors of the chronometers in April, were those obtained in London before the ships sailed; those on the 25th August were determined at the Observatory on Dane's Island, Spitzbergen, the longitude of which was determined by a great many observations of the distances of the sun and moon for several days with TROUGHTON's eight inch sextants and reflecting circles. The rates in the column entitled "Mean Rates at Sea," are deduced by dividing the difference of the errors by the interval.

The rates in the column entitled "Mean Rates on Shore," or more properly what they *would have had*, are means between the rates of chronometers on shore before leaving England, and those obtained at Spitzbergen; and although a mean between the rates of chronometers obtained at different times, may not accurately be the mean rate they would have had during the interval of those times, from the continued variation to which they are subject; yet, upon comparing the two last columns together, of the rates thus deduced, it will be perceived, that in all the chronometers their gaining rates had either been increased, or their losing ones diminished on ship-board, or in other words, they had all been accelerated.

Nor is this acceleration peculiar to high latitudes; it was observed very soon after the chronometers were put on board in the River, particularly in Nos. 3 and 8, which, upon arriving at Shetland, were found to have gained instead of losing rates, which they had in London.

This acceleration was very soon perceptible in the chronometers taken out by the Hon. Captain PHIPPS, made by

KENDAL and **ARNOLD**. **Mr. LYONS**, who accompanied him, landed at **Sheerness Fort**, and found the longitude by them to be $30^{\circ} 0''$ E, which is about $13'$ W of the true longitude, as determined in the **Trigonometrical Survey**.

The same occurrence took place last summer (1819). The longitude of a place in one of the **Orkney Islands**, as determined by three chronometers made by **ARNOLD**, two of them belonging to myself, the other to **Lieut. E. HOME, R. N.** who accompanied me, was $6' 40''$ W. of the longitude determined by the difference of Δ of stars E and W of Δ .

Again, in the trial of **Mr. HARRISON's** timekeeper, in 1764, the longitude of **Barbadoes** by the watch was $10' 45''$ more to the westward than that determined by astronomical observations made by the persons sent out for that purpose.

Soon after this trial, the commissioners of longitude agreed with **Mr. KENDAL**, one of the watchmakers appointed by them to receive **Mr. HARRISON's** discoveries, to make another watch on the same construction, which went considerably better than **Mr. HARRISON's**. **Mr. KENDAL's** watch was sent out with **Captain COOK** in his second voyage towards the **South Pole** and round the world, in the years 1772-3-4 and 5, "when the only fault found in the watch was, that its rate of "going was continually accelerated."

It now remains, therefore, to determine what this acceleration arises from. That it does not arise from the motion of the vessels, is evident in the case of the nine chronometers on board the **Dorothea** and **Trent**; since the acceleration was observed when the ships were firmly beset with ice; also in the case of the alteration in the rates of the chronometers upon

landing, and taking them on board again at Dane's Island, the ships were riding at anchor close in shore without any perceptible motion.

An account was also kept on board and on shore, of the state of the temperature and barometer, every two hours, both night and day ; and upon comparing them together, there does not appear to be the least correspondence between the change of rates and the temperature at the time.

It appears therefore to me, that this acceleration arose entirely from the magnetic action exerted by the iron in the ship on the inner rim of the balance, which is made of steel.

That the iron in the ships becomes magnetic, is plain, from the polarity which exists in it ; the whole forming altogether one large magnet, having its south pole on deck nearly amidships, and its north pole below. This is seen from the constant deviation of the north end of the compasses placed on deck towards the centre of the ship, as appears from recent observations, which I have mentioned elsewhere.

Nor is it surprising that the force exerted by the ship's iron (thus become magnetical) on the balance of the chronometers, should be sufficient to cause a very sensible alteration in the rate of going, when we consider how easily, in other cases, the presence of any thing magnetical is detected by the alteration of the rate of a chronometer ; and when we consider the great influence exerted by this iron upon the binnacle compasses at very considerable distances, and in situations where the utmost precaution is used to remove every piece of iron from them, by using copper-bolts, fastenings, &c.

It remains only to determine, how far this alteration in the

rates of the chronometers, can be reconciled with that observed in chronometers when under the influence of magnets placed in different positions with respect to their balances.

To determine this, two watches were used, with steel balances and horizontal escapements, one by EARNSHAW, the other by ALLAN and CAITHNESS; also two chronometers made by ARNOLD. To each of these watches were applied, at a distance of two inches from the balance, magnets of twelve inches in length, in four different positions, and in the planes of the balances.

The following Table will show the rates of the watches in twenty-four hours, deduced by comparing them with an excellent clock with GRAHAM's dead beat escapement, and regulated by transit.

	No. 1.	No. 2.			No. 3.	No. 4.
N	+9.15	+5.0	3	N	+0.34	+0.41
S	+8.12	+21.0		S	+2.18	+0.44
N	+8.0	+18.0	6	N	+1.28	-1.43
S	+48.0	+8.0		S	+5.27	-0.36
N	+47.10	+17.8	9	N	+5.22	+1.3
S	+72.0	+8.44		S	-0.14	+0.41
N	+4.14	+4.32	12	N	+2.47	+1.12
S	-2.0	+15.0		S	-1.2	+1.24

The first column in this table shows the pole of the magnet applied to the watch; the second and third, the rate or effect produced on each watch; the fourth column shows the figure on the face of the watch opposite to which the magnet was applied.

The watch, No. 1, gained with both poles, and in every position of the magnet but one. No. 2, gained with both poles in every position. Nos. 3 and 4 gained in every position but two; and the quantities lost in the positions were far exceeded by the accelerations caused by the opposite poles, excepting one case in that of No. 4.

The magnets were likewise placed in different positions out of the planes of the balances; the results were very *similar* to those above, but differing in quantity, according to the distance of the magnets from the planes of the balances.

Upon placing the magnets very near to the rim of the balances, a very rapid acceleration took place with both poles, and in every position of the magnets, particularly in the watches Nos. 1 and 2. Upon too near an approach of the magnets, the watch No. 1, and chronometer No. 3, were rendered useless; the former, when the magnets were taken away, gaining no less than about $1\frac{1}{4}$ hour, and the chronometer losing about 50" in 24 hours; and in again repeating the experiments in the plane of the balances, the rates of the chronometers (without the magnets) were so variable, that it was necessary to determine their rates before and after each application of the magnets; the following, however, is a Table of the results upon the chronometers Nos. 3 and 4.

	No. 3.	No. 4.	
N	+ 0. 2.7	+ 0.43.5	3
S	+ 1.24	+ 0.46	
N	- 5.32	- 1.40	6
S	+ 6.15	- 1.37	
N	+ 5.19	+ 1.18	9
S	- 1.53	+ 1.12	
N	+ 1.59	+ 1.11.7	12
S	+ 2. 7.3	+ 1.29	
N	+ 0.31	+ 1.14	3
S	+ 2. 8	+ 0.43	
N	- 5. 9	- 1.24	6
S	+ 4.25.7	- 0.59	
N	+ 5.25	+ 0.55	9
S	- 1.53	+ 0.42	
N	+ 2.33	+ 1.5	12
S	- 2.23	+ 1.6	

Each of these results in this Table, is the difference of the rates when the magnets were applied, and a mean of the rates of the chronometers before and after the application of the magnets. The rate of the chronometer No. 3, is very different from that given in the former Table ; that of No. 4, is nearly the same, and does not appear to have been affected, as No. 3 was, by the close approach of the magnet.

Upon the whole, however, it appears that chronometers will be generally accelerated (particularly if their balances

have not received polarity by the too near approach of any thing magnetical) on ship-board. It appears probable, likewise, that the force of the balance springs is affected in the same way; since it is well known that chronometers having gold balance springs, although more difficult to adjust, yet keep better rates at sea than the others.

However this may be, these observations show the necessity of not trusting to the rates of chronometers ascertained during the time they are on shore; and if the rates are ascertained on board, the chronometers should always be kept in the same place, and also in the same position with respect to the ship; for I have but little doubt that, upon an accurate trial, a chronometer will be found to change its rate, more or less, according as these circumstances are attended to. If these precautions are not taken, land will appear to be considerably to the westward of its true position; this is particularly exemplified in the observations of the Hon. Captain PHIPPS; from which, nearly the whole line of coast on the west side of East Greenland has been placed nearly $1\frac{1}{2}^{\circ}$ too much to the westward, by reason of the acceleration of his chronometers; the same circumstance would have occurred with the chronometers in both of the ships Dorothea and Trent, in the late voyage, had not the longitude been otherwise determined. It is therefore highly requisite that attention should be paid to a circumstance so much connected with the improvement of geography as well as the safety of the seaman.

As an Appendix to these observations, I beg leave to add the following Table of Rates, furnished by Mr. COLEMAN, to which I have prefixed his letter as an introduction.

157, Leadenhall-Street,

5th June, 1820.

SIR,

IN compliance with the wish of our common friend Lieutenant EVERARD HOME, I have much pleasure in sending you a table of rates of chronometers. My profession as Teacher of Navigation, conjointly with Mr. NORIE, which connects me so intimately with the Officers of the Honourable East India Company, employed on board the ships trading to India, has enabled me to present you with this table upon an enlarged scale. While engaged in the same service eighteen years, this subject occupied my attention, and it affords me much satisfaction that you are bringing the subject before the Royal Society. My remarks correspond very much with those, I understand, you are now bringing forward.

I am, Sir,

Your obedient servant,

GEORGE COLEMAN.

TABLE I. A

Date.	Persons' Names.	Ships' Names.	Burthen in Tons.	Copper or Iron fastened.	Chronometers.	No. of Days to wind up.	Rates given.	Rates
1802 & 1803	Capt. Dunsford	H. C. S. Ceres	1200	Iron	Arnold Margetts Margetts Earnshaw	1 8 8 1	3.4 gaining 5.0 gaining 2.5 losing 6.2 losing	5.0 ga 5.2 ga 2.0 lo 7.5 lo
1804 & 1805	Capt. Dunsford	H. C. S. Ceres	1200	Iron	Arnold Margetts Earnshaw	1 8 1	4.5 gaining 5.0 gaining 6.4 losing	6.0 ga 5.2 ga 8.0 los
1806 & 1807	Capt. Dunsford	H. C. S. Ceres	1200	Iron	Arnold Arnold Margetts Earnshaw	1 1 8 1	2.5 gaining 4.6 losing 5.0 gaining 1.4 losing	3.8 ga 4.0 los 5.3 ga 1.5 ga
1808 & 1809	Capt. Dodds	H. C. S. Walmer Castle	1260	Iron	Barraud Brockbank Arnold	1 8 1	7.3 gaining 4.0 losing 3.6 gaining	6.0 ga 2.8 los 4.0 ga
1810 & 1811	Capt. Mayne Mr. Coleman	H. C. S. Batavia	750	Iron	Earnshaw Arnold Brockbank	1 1 2	6.7 losing 3.7 gaining 11.8 losing	3.2 los 5.4 ga 13.8 los
1812	Capt. Mayne Mr. Coleman	H. C. S. Batavia	750	Iron	Earnshaw Arnold Brockbank	1 1 2	10.5 gaining 6.7 gaining 15.4 losing	18.0 and 2.4 gain 15.6 los
1813 & 1814	Capt. Blanchard Capt. Money Mr. Coleman Mr. Decharme	H. C. S. James Sibbald	700	Iron	The Book containing the various changes of these Chronometers N. B. The above Chronometers were all under my entire care			

TABLE I. A.

To face p. 208.

Rates given.	Rates found.	Difference of Rates.	REMARKS.
4 gaining 0 gaining 5 losing 2 losing	5.0 gaining 5.2 gaining 2.0 losing 7.5 losing	1.6 gained 0.2 gained 0.5 gained 1.3 lost	} These Chronometers went remarkably steady during the voyage, with the rates found.
5 gaining 0 gaining 4 losing	6.0 gaining 5.2 gaining 8.0 losing	1.5 gained 0.2 gained 1.6 lost	} These Chronometers gained on board the same as on the preceding voyage. This also <i>lost</i> in <i>similar proportion</i>
5 gaining 3 losing 0 gaining 4 losing	3.8 gaining 4.0 losing 5.3 gaining 1.5 gaining	1.3 gained 0.6 gained 0.3 gained 2.9 gained	The same Chronometer as above, same alteration. This Chronometer went five years at 5" on shore, and 5.3 on board. The same Chronometer as above, altered after cleaning.
3 gaining 0 losing 6 gaining	6.0 gaining 2.8 losing 4.0 gaining	1.3 lost 1.2 gained 0.4 gained	
7 losing 7 gaining 3 losing	3.2 losing 5.4 gaining 13.8 losing	3.5 gained 1.7 gained 2.0 lost	This Chronometer went very irregular during the voyage.
Calcutta upwards of three months, and then had the following rates given and found.			
5 gaining 7 gaining 4 losing	18.0 and 23" gaining 2.4 gaining 15.6 losing 1.7 gained 3.2 lost	NO reliance on this Chronometer at any time. This Chronometer gradually lost during the whole voyage.
ous changes of these Chronometers is in Captain Blanchard's possession, whose arrival in England is daily expected.			
eters were all under my entire charge ; I therefore can vouch for the accuracy of the above statements.—G. COLEMAN.			

TABLE I. B.

Date.	Persons' Names.	Ships' Names.	Burthen in Tons.	Copper or Iron fastened.	Chronometers.	No. of Days to wind up.	Rates given.	Rates found.
1819 & 1820	Capt. Tennent	H. C. S. Apollo	700	Iron	Barraud Barraud Brockbank & Co.	1 8 2	" 3.0 losing 3.5 gaining 9.5 gaining	" 2.5 losing 4.2 gaining 12.5 and 14
1818 & 1819	Capt. S. Lee	H. C. S. Moffatt	720	Iron	Brockbank Barraud	1 2	4.5 losing 2.4 gaining	3.2 losing 3.6 gaining
1819 & 1820	Capt. Stewart.	F. T. Sappho	360	Copper	Barraud Hatton Parkinson & Co.	8 8 1	6.8 losing 2.4 gaining 10.0 gaining	5.0 losing 7.0 gaining 16.5 and 20
1819	Capt. Pitcher	F. T. Bloxbornbury	720	Copper	Morris	1	2.2 gaining	3.5 gaining
1818 1819	Capt. Foord	S. S. Phoenix	460	Iron	Brockbank & Co.	2	3.5 losing	6.3 losing
1815 & 1816	Capt. Forbes	H. C. S. James Sibbald	700	Iron	Hatton Barraud Earnshaw	8 1 p. 1	14.0 gaining Going at mean time 15.0 losing	14.0 gaining 0.3 gaining 18.5 losing
On the Ship's returning home, the above Chronometers had rates as under, after being								
					Hatton Earnshaw	8 1	14.5 gaining 19.2 losing	16.0 gaining 20.7 losing
1818 & 1819	Capt. Forbes	H. C. S. James Sibbald	700	Iron	Hatton & Harris Hatton & Harris Barraud	8 1 p. 1 p.	9.5 losing 3.0 gaining 4.5 losing	8.5 losing 5.0 gaining 6.0 losing
On the homeward bound passage, the same Chronometers had the following								
					Hatton & Harris Hatton & Harris Barraud	8 1 p. 1 p.	9.0 losing 5.0 gaining 7.0 losing	9.0 losing 5.0 gaining 7.0 losing
1819 1820	Capt. Doveton	T. F. Lotus	580	Copper	Barraud	8	6.8 losing	8.0 losing

TABLE I. B.

Rates given.	Rates found.	Difference of Rates.	REMARKS.
losing gaining gaining	" 2.5 losing 4.2 gaining 12.5 and 16 gaining	" 0.5 gained 0.7 gained 6.5 gained	} Barraud's Chronometers went steady several months before they altered their rates ; but Brockbank's altered its rate in a few weeks.
losing gaining	3.2 losing 3.6 gaining	1.3 gained 1.2 gained	} These Chronometers went steady within 2 or 3 tenths, during a voyage of fourteen months.
losing gaining gaining	5.0 losing 7.0 gaining 16.5 and 22 gaining	1.8 gained 4.6 gained 12.0 gained	} These went pretty regular with ship rates. This Chronometer proved a very bad one.
gaining	3.5 gaining	1.3 gained	
losing	6.3 losing	2.8 lost	This Chronometer went steady at 6.3 till let down.
0 gaining g at mean time 0 losing	14.0 gaining 0.3 gaining 18.5 losing 0.3 gained 3.5 lost	No difference was discovered in the going of this Chronometer outward. This Chronometer going well at 0.3, was sold at Calcutta. Altered its rate after leaving Madeira.
had rates as under, after being eleven weeks on shore at Calcutta.			
5 gaining 2 losing	16.0 gaining 20.7 losing	1.5 gained 1.5 lost	} The Chronometers went very steady during the homeward passage with the rates found.
5 losing 0 gaining 5 losing	8.5 losing 5.0 gaining 6.0 losing	0.5 gained 2.0 gained 1.5 lost	} These Chronometers were rated at Madeira, and afterwards went steady at those rates.
Chronometers had the following rates, after being three months on shore.			
0 losing 0 gaining 0 losing	9.0 losing 5.0 gaining 7.0 losing		} It therefore appears the Chronometers did <i>not vary</i> their rates homeward in the most trifling degree.
8 losing	8.0 losing	1.2 lost	This Chronometer did not alter its rate till at Calcutta.

TABLE

Date.	Persons' Names.	Ships' Names.	Ton- nage.	Iron or Copper fastened.	Makers of Chronometers.	No. of Days to wind up.	Box or Pocket.	Rates
1802 & 1803	Capt. Dunsford	H. C. S. Ceres	1200	Iron	Arnold Margetts Ditto Earnshaw	1 8 8 1	Pocket Box — Pocket	3.4 gai 5.0 gai 2.5 los 6.2 los
1804 & 1805	Capt. Dunsford	H. C. S. Ceres	1200	Iron	Arnold Margetts Earnshaw	1 8 1	Pocket Box Pocket	4.5 gai 5.0 gai 6.4 los
1806 & 1807	Capt. Dunsford	H. C. S. Ceres	1200	Iron	Arnold Ditto Margetts Earnshaw	1 1 8 1	Pocket — Box Pocket	2.5 gai 4.6 los 5.0 gai 1.4 los
1808 & 1809	Capt. Dodds	H. C. S. Walmer Castle	1200	Iron	Barraud Brockbank Arnold	1 8 1	Pocket Box Pocket	7.3 gai 4.0 los 3.6 gai
1810 & 1811	Capt Mayne Mr. Coleman	H. C. S. Batavia	750	Iron	Earnshaw Arnold Brockbank	1 1 2	Box Pocket Box	6.7 los 3.7 gai 11.8 los
1812	Capt. Mayne Mr. Coleman				Earnshaw Arnold Brockbank	1 1 2	Box Pocket Box	10.5 gai 6.7 gai 15.4 los
1813 & 1814	Capt. Blanchard Capt. Money Mr. Coleman Mr. Decharme	H. C. S. James Sibbald	700	Iron	Hatton Barraud Ditto Brockbank Ditto Barraud	8 2 1 1 1 1	Box — Pocket Box — Pocket	7.2 gai 2.4 gai 3.5 los 10.8 los 4.4 gai 2.6 gai
1819 & 1820	Capt. Tennent	H. C. S. Apollo	700	Iron	Barraud Barraud Brockbank	1 8 2	Box — —	3.0 los 3.5 gai 9.5 gai
1818 & 1819	Capt. S. Lee	H. C. S. Moffatt	720	Iron	Brockbank Barraud	1 2	Box —	4.5 los 2.4 gai
1815 & 1816	Captain Forbes	H. C. S. James Sibbald	700	Iron	Hatton Barraud Earnshaw	8 1 1	Box Pocket Box	14.0 g On me 15.0 l
					Hatton Earnshaw	8 1	Box —	14.5 gai 19.2 los

The above Chronometers were on shore at Calcutta upwards

These Chronometers were on shore about eleven w

TABLE II. A.

	Iron or Copper fastened.	Makers of Chronometers.	No. of Days to wind up.	Box or Pocket.	Rates given.	Rates found.	Difference of Rates.	
0	Iron	Arnold Margetts Ditto Earnshaw	1 8 8 1	Pocket Box — Pocket	3.4 gaining 5.0 gaining 2.5 losing 6.2 losing	5.0 gaining 5.2 gaining 2.0 losing 7.5 losing	1.6 gained 0.2 gained 0.5 gained 1.3 lost	} These Chronometers the rates for
00	Iron	Arnold Margetts Earnshaw	1 8 1	Pocket Box Pocket	4.5 gaining 5.0 gaining 6.4 losing	6.0 gaining 5.2 gaining 8.0 losing	1.5 gained 0.2 gained 1.6 lost	} These Chronometers as in the previous This Chronometer
00	Iron	Arnold Ditto Margetts Earnshaw	1 1 8 1	Pocket — Box Pocket	2.5 gaining 4.6 losing 5.0 gaining 1.4 losing	3.8 gaining 4.0 losing 5.3 gaining 1.5 gaining	1.3 gained 0.6 gained 0.3 gained 2.9 gained	In the two forms This Chronometer This Chronometer Same Chronometer
00	Iron	Barraud Brockbank Arnold	1 8 1	Pocket Box Pocket	7.3 gaining 4.0 losing 3.6 gaining	6.0 gaining 2.8 losing 4.0 gaining	1.3 lost 1.2 gained 0.4 gained	} These Chronometers
0	Iron	Earnshaw Arnold Brockbank	1 1 2	Box Pocket Box	6.7 losing 3.7 gaining 11.8 losing	3.2 losing 5.4 gaining 13.8 losing	3.5 gained 1.7 gained 2.0 lost	This Chronometer

The above Chronometers were on shore at Calcutta upwards of three months, and then had the following rates given and found.

		Earnshaw Arnold Brockbank	1 1 2	Box Pocket Box	10.5 gaining 6.7 gaining 15.4 losing	18.0 and 23 gaining 8.4 gaining 18.6 losing 1.7 gained 3.2 lost	No reliance on This Chronometer
00	Iron	Hatton Barraud Ditto Brockbank Ditto Barraud	8 2 1 1 1 1	Box — Pocket Box — Pocket	7.2 gaining 2.4 gaining 3.5 losing 10.8 losing 4.4 gaining 2.6 gaining	7.2 gaining 3.2 gaining 2.0 losing 12.6 losing 5.8 gaining 2.6 gaining	No difference 0.8 gained 1.5 gained 1.8 lost 1.4 gained No difference	} These Chronometers Money's box
00	Iron	Barraud Barraud Brockbank	1 8 2	Box — —	3.0 losing 3.5 gaining 9.5 gaining	2.5 losing 4.2 gaining 12.5 then 16 ditto	0.5 gained 0.7 gained 16.5 gained	} These Chronometers This was a very
00	Iron	Brockbank Barraud	1 2	Box —	4.5 losing 2.4 gaining	3.2 losing 3.6 gaining	1.3 gained 1.2 gained	These scarcely
00	Iron	Hatton Barraud Earnshaw	8 1 1	Box Pocket Box	14.0 gaining On mean time. 15.0 losing	14.0 gaining 0.3 gaining 18.5 losing	No difference 0.3 gained 3.5 lost	Chronometer with

These Chronometers were on shore about eleven weeks, and then the following rates were both given and found.

		Hatton Earnshaw	8 1	Box —	14.5 gaining 19.2 losing	16.0 gaining 20.7 losing	1.5 gained 1.5 lost	} These went very
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A.

To follow Table I.

Rates found.	Difference of Rates.	REMARKS.
5.0 gaining 5.2 gaining 2.0 losing 7.5 losing	1.6 gained 0.2 gained 0.5 gained 1.3 lost	} These Chronometers went remarkably well during the voyage, with the rates found.
6.0 gaining 5.2 gaining 8.0 losing	1.5 gained 0.2 gained 1.6 lost	} These Chronometers gained during this voyage in the same proportion as in the preceding one. This Chronometer <i>lost</i> in similar proportion.
3.8 gaining 4.0 losing 5.3 gaining 1.5 gaining	1.3 gained 0.6 gained 0.3 gained 2.9 gained	In the two former voyages there was nearly the same alteration. This Chronometer a very excellent one. This Chronometer went five years & a half at 5". on shore, and 5".3 on board. Same Chronometer as mentioned on a former voyage.
6.0 gaining 2.8 losing 4.0 gaining	1.3 lost 1.2 gained 0.4 gained	} These Chronometers went very steady with the rates given them.
3.2 losing 5.4 gaining 13.8 losing	3.5 gained 1.7 gained 2.0 lost	This Chronometer went irregular during the whole voyage.

months, and then had the following rates given and found.

18.0 and 23 gaining 8.4 gaining 18.6 losing 1.7 gained 3.2 lost	No reliance on this Chronometer at any time. This Chronometer gradually lost during the whole voyage.
7.2 gaining 3.2 gaining 2.0 losing 12.6 losing 5.8 gaining 2.6 gaining	No difference 0.8 gained 1.5 gained 1.8 lost 1.4 gained No difference	} These Chronometers went remarkably well with the ship, except Capt. Money's box one, which at times veered and hauled exceedingly.
2.5 losing 4.2 gaining 12.5 then 16 ditto	0.5 gained 0.7 gained 16.5 gained	} These Chronometers went extremely well during the whole voyage. This was a very indifferent one throughout.
3.2 losing 3.6 gaining	1.3 gained 1.2 gained	These scarcely varied from the rates found during the whole voyage.
14.0 gaining 0.3 gaining 18.5 losing	No difference 0.3 gained 3.5 lost	Chronometer was sold at Calcutta.

and then the following rates were both given and found.

16.0 gaining 20.7 losing	1.5 gained 1.5 lost	} These went very steady on the passage home with the rates found.
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TABLE

Date.	Persons' Names.	Ships' Names.	Ton- nage.	Iron or Copper fastened.	Makers of Chronometers.	No. of Days to wind up.	Box or Pocket.	Rates
1818 & 1819	Capt. Forbes	H. C. S. James Sibbald	700	Iron	Hatton Ditto Barraud	8 1 1	Box Pocket —	9.5 los 3.0 gai 4.5 los
					On the Homeward passage the above Chronometers had the			
					Hatton Ditto Barraud	8 1 1	Box Pocket —	9.0 los 5.0 gai 7.0 los
1819 & 1820	Capt Stewart	Ship Sappho	360	Copper	Barraud Hatton Parkinson	8 8 1	Box — —	6.8 los 2.4 gai 10.0 gai
1818 1819	Capt. Pitcher	H. C. S. Bloxbornbury	720	Copper	Morris	1	Pocket	2.2 gai
1818 1819	Capt. Foord	S. S. Phœnix	460	Copper	Brockbank	2	Box	3.5 los
1819 1820	Capt. Doveton	Lotus	580	Copper	Barraud	8	Box	6.8 los
1818 & 1819	Capt. W. Morgan	Layton	400	Iron	Barraud Ditto - Homeward bound	2	Box	6.0 los 7.0 los
1819 & 1820	Capt. Ogelvie	Juliana	448	Iron	Barraud Ditto - Homeward bound	1	Box	6.0 los 6.0 los
1819 1820	Capt. Scott	H. C. S. Charles Grant	1200	Copper	Barraud	8	Box	6.1 los
1814 1815	Capt. Hope	H. C. S. Surat Castle	1200	Iron	Barraud	8	Box	1.8 gai
1816 1817	Capt. Hope	H. C. S. Surat Castle	1200	Iron	Same Chronom.	8	Box	5.2 gai
1813 1814	Capt. Franklin	H. C. S. Northumberland	640	Iron	Barraud	8	Box	0.4 los
1814 1815	Capt. Cameron	H. C. S. Ann	610	Iron	Barraud	8	Box	2.0 gai
1816 1817	Capt. B. Laing	H. C. S. Royal Charlotte	1200	Iron	Barraud	8	Box	0.0
1818	Capt. M'Kellar, R. N.	H. M. S. Pique			Barraud	8	Box	6.5 los
					Next six months on ship its rate was			
1818 & 1819	Capt. Taylor	Cæsar	510	Copper	Barraud	8	Box	2.7 los
					Next twelve months on shore, its rate was 0.			

TABLE II. B.

n- e.	Iron or Copper fastened.	Makers of Chronometers.	No. of Days to wind up.	Box or Pocket.	Rates given.	Rates found.	Difference of Rates.	
00	Iron	Hatton Ditto Barraud	8 1 1	Box Pocket —	9.5 losing 3.0 gaining 4.5 losing	8.5 losing 5.0 gaining 6.0 losing	0.5 gained 2.0 gained 1.5 lost	} These Chrono- rates on th
On the Homeward passage the above Chronometers had the following rates given and found, after being on shore three months								
		Hatton Ditto Barraud	8 1 1	Box Pocket —	9.0 losing 5.0 gaining 7.0 losing	9.0 losing 5.0 gaining 7.0 losing	{ No differ- ence.	} It therefore a given them
50	Copper	Barraud Hatton Parkinson	8 8 1	Box — —	6.8 losing 2.4 gaining 10.0 gaining	5.0 losing 7.0 gaining 16.5 then 22 gaining	1.8 gained 4.6 gained 12.0 gained	} These went r This very indiffe
00	Copper	Morris	1	Pocket	2.2 gaining	3.5 gaining	1.3 gained	
00	Copper	Brockbank	2	Box	3.5 losing	6.3 losing	2.8 lost	This Chronome
00	Copper	Barraud	8	Box	6.8 losing	8.0 losing	1.2 lost	On being lande
00	Iron	Barraud Ditto - Homeward bound	2	Box	6.0 losing 7.0 losing	7.2 losing 6.2 losing	1.2 lost 0.8 gained	
18	Iron	Barraud Ditto - Homeward bound	1	Box	6.0 losing 6.0 losing	6.0 losing 5.2 losing	No difference 0.8 gained	
00	Copper	Barraud	8	Box	6.1 losing	5.4 losing	0.7 gained	
00	Iron	Barraud	8	Box	1.8 gaining	0.0	1.8 lost	
00	Iron	Same Chronom.	8	Box	5.2 gaining	5.5 gaining	0.3 gained	
40	Iron	Barraud	8	Box	0.4 losing	0.0	0.4 gained	
10	Iron	Barraud	8	Box	2.0 gaining	1.6 gaining	0.4 lost	
00	Iron	Barraud	8	Box	0.0	0.4 gaining	0.4 gained	
		Barraud Next six months on ship its rate was	8	Box	6.5 losing 6.5 losing	6.2 losing	0.3 gained	} This Chronom
10	Copper	Barraud Next twelve months on shore, its rate was	8	Box	2.7 losing 0.1 gaining	1.9 losing	0.8 gained	

B,

	Rates found.	Difference of Rates.	REMARKS.
	" 8.5 losing 5.0 gaining 6.0 losing	" 0.5 gained 2.0 gained 1.5 lost	} These Chronometers were all rated at Madeira, and went steady at those rates on the passage out.
g rates given and found, after being on shore three months and upwards.			
	9.0 losing 5.0 gaining 7.0 losing	{ No difference.	} It therefore appears that these Timekeepers did <i>not vary</i> from the rates given them on shore in the smallest degree.
	5.0 losing 7.0 gaining 16.5 then 22 gaining	1.8 gained 4.6 gained 12.0 gained	} These went regular with the rates found. This very indifferent during the whole voyage.
	3.5 gaining	1.3 gained	
	6.3 losing	2.8 lost	This Chronometer went steady at 6.3 till let down.
	8.0 losing	1.2 lost	On being landed, it returned to its first rate—6.8 losing.
	7.2 losing 6.2 losing	1.2 lost 0.8 gained	
	6.0 losing 5.2 losing	No difference 0.8 gained	
	5.4 losing	0.7 gained	
	0.0	1.8 lost	
	5.5 gaining	0.3 gained	
	0.0	0.4 gained	
	1.6 gaining	0.4 lost	
	0.4 gaining	0.4 gained	
	6.2 losing	0.3 gained	} This Chronometer returned to the maker's rate on being brought on shore.
ng	1.9 losing	0.8 gained	

TABLE

Date.	Persons' Names.	Ships' Names.	Ton- nage.	Iron or Copper fastened.	Makers of Chronometers.	No. of Days to wind up.	Box or Pocket.	Rates
1817	Capt. Sever	West India S. Fanny	384	Iron	Barraud	8	Box	0.5 loss
1818	Ditto	Ditto			Ditto	Next four months on shore		0.2 gain
1819	Ditto	Ditto			Ditto	Next two months on shore		0.7 gain
1818	Capt. James Kay	H. C. S. Marchioness of Exeter - - }	980	Copper	Barraud Ditto	8	Box	4.0 loss
						Next four months on shore		
1817	Capt. R. S. Dalrymple	H. C. S. Vansittart	1240	Copper	Barraud	8	Box	0.6 gain
1818					Ditto	Next six months on shore		
1819	Ditto	Ditto			Ditto	8	Box	0.4 loss
1820					Ditto	Since the ship's return to L		
1817 & 1818	Capt. Nairne	H. C. S. General Kyd	1240	Iron	Barraud Ditto	2	Box	1.5 gain
						Next six months on shore		
1816	Capt. R. Drew	West India Ship			Barraud	2	Box	9.3 gain
1817					Ditto	Next five months on shore		
1817	Ditto	Ditto			Ditto			8.4 gain
1818					Ditto	Next three months on shore		
1818	Ditto	Ditto			Ditto			4.5 gain
1819					Ditto	Next thirty-two days on shore		
1819	Capt. Cookesley	Ship Malida	480	Copper	Barraud Ditto	2	Box	6.5 loss
						Next forty days on shore..		
1818 & 1819	Capt. Johnson	H. C. S. Camden	490	Iron	Barraud	2	Box	Going m
1816	Capt. Barwick				Barraud	2	Box	0.0 to
					On shore this Chronometer still increased to 11.5 gain			
1816 & 1817	Capt. Tremenhere	H. C. S. Asia	890	Iron	Barraud Ditto	8	Box	2.0 gain
						Next six months on shore		
1817	Capt. Auber	E. I. S. Lady Raffles	610	Iron	Barraud	2	Box .	5.0 gain
1816	Capt. Druce				Barraud	1	Pocket	2.5 loss
1815 1816	Capt. Mortlock	H. C. S. Lowther Castle	1200	Copper	Barraud	1	Pocket	1.8 loss
1819 & 1820	Capt. Gribble	H. C. S. Princess Char- lotte of Wales - }	978	Iron	Barraud	8	Box	11.0 loss
						8	Box	2.0 gain

TABLE II. C.

on- ge.	Iron or Copper fastened.	Makers of Chronometers.	No. of Days to wind up.	Box or Pocket.	Rates given.	Rates found.	Difference of Rates.	
34	Iron	Barraud Ditto Ditto Ditto Ditto	8 Next four months 8 Next two months	Box on shore Box on shore	0.5 losing 0.2 gaining 0.7 gaining	" 0.9 gaining 2.0 gaining 1.4 gaining 0.7 gaining 1.4 gaining	" 1.4 gained 0.6 lost 0.7 gained	In this instance
30	Copper	Barraud Ditto	8 Next four months	Box on shore	4.0 losing	4.1 losing 3.3 losing	0.1 lost	
40	Copper	Barraud Ditto Ditto Ditto	8 Next six months 8 Since the ship's return to England..	Box on shore Box on shore	0.6 gaining 0.4 losing	0.2 gaining 0.7 losing 0.8 losing 0.2 gaining	0.4 lost 0.4 lost	} It therefore a and the sa cessary to
40	Iron	Barraud Ditto	2 Next six months	Box on shore	1.5 gaining	1.7 gaining 3.0 gaining	0.2 gained	
		Barraud Ditto Ditto Ditto Ditto Ditto	2 Next five months 8.4 Next three months 4.5 Next thirty-two days	Box on shore gaining on shore gaining on shore	9.3 gaining 8.4 6.5 5.0	10.3 gaining 8.4 gaining 8.9 gaining 8.0 gaining 6.5 gaining 5.0 gaining	1.0 gained 0.5 gained and then gradually decreased 2.0 gained and was then cleaned.	
30	Copper	Barraud Ditto	2 Next forty days	Box on shore	6.5 losing	6.5 losing 8.0 losing	No difference	} This Chrono rate of 6.5
30	Iron	Barraud	2	Box	Going mean time	9.3 gaining	9.3 gained	} This increas months, at following following
		Barraud	2	Box	0.0 to	9.5 gaining	in the course of thirteen mont	
		On shore this Chronometer still increased to 11.5 gaining				12.2 gaining	0.7 gained	And went at 12
0	Iron	Barraud Ditto	8 Next six months	Box on shore	2.0 gaining	2.3 gaining 3.7 gaining	0.3 gained and was then cleaned.	
0	Iron	Barraud	2	Box .	5.0 gaining .	7.8 gaining	2.8 gained	And went next 1
		Barraud	1	Pocket	2.5 losing	3.4 losing	0.9 lost	And went next
00	Copper	Barraud	1	Pocket	1.8 losing	1.7 losing	0.1 gained	And went next
8	Iron	Barraud	8 8	Box Box	11.0 losing 2.0 gaining	12.2 losing 2.3 gaining	1.2 lost 0.3 gained	Since the ship's

E. C.

	Rates found.	Difference of Rates.	REMARKS.
...	" 0.9 gaining 2.0 gaining 1.4 gaining 0.7 gaining 1.4 gaining	" 1.4 gained 0.6 lost 0.7 gained	In this instance it returned to the same rate as on the <i>preceding</i> voyage.
...	4.1 losing 3.3 losing	0.1 lost	
... d..	0.2 gaining 0.7 losing 0.8 losing 0.2 gaining	0.4 lost 0.4 lost	} It therefore appears this Chronometer varied precisely the same quantity and the same way, two succeeding voyages : this ship, it may be necessary to remark, is copper fastened throughout.
...	1.7 gaining 3.0 gaining	0.2 gained	
...	10.3 gaining 8.4 gaining 8.9 gaining 8.0 gaining 6.5 gaining 5.0 gaining	1.0 gained 0.5 gained and then gradually decreased to 4.5, the rate when taken on board. 2.0 gained and was then cleaned.	
...	6.5 losing 8.0 losing	No difference	} This Chronometer, since its return on board ship, has taken up again the rate of 6.5, which favours Mr. Fisher.
ne	9.3 gaining	9.3 gained	} This increase of rate took place very gradually during the first four months, after which it kept that rate, making an error of <i>only</i> 16". the following fifteen <i>months</i> , and continued the <i>same</i> rate for five months following <i>on shore</i> ; was then cleaned.
	9.5 gaining 12.2 gaining	in the course of thirteen months at sea, and the following two months. 0.7 gained	And went at 12.2, gaining next three months on shore.
...	2.3 gaining 3.7 gaining	0.3 gained and was then cleaned.	
	7.8 gaining	2.8 gained	And went next four months on shore at 5.5 gaining
	3.4 losing	0.9 lost	And went next eleven months on shore at 0.3 losing.
	1.7 losing	0.1 gained	And went next forty days on shore at 2.1 losing ; then cleaned.
	12.2 losing 2.3 gaining	1.2 lost 0.3 gained	Since the ship's arrival it has been going at 14.8 losing. 1.9 gaining.